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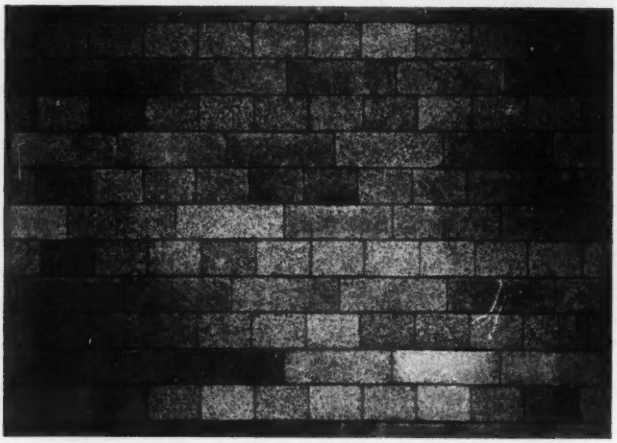

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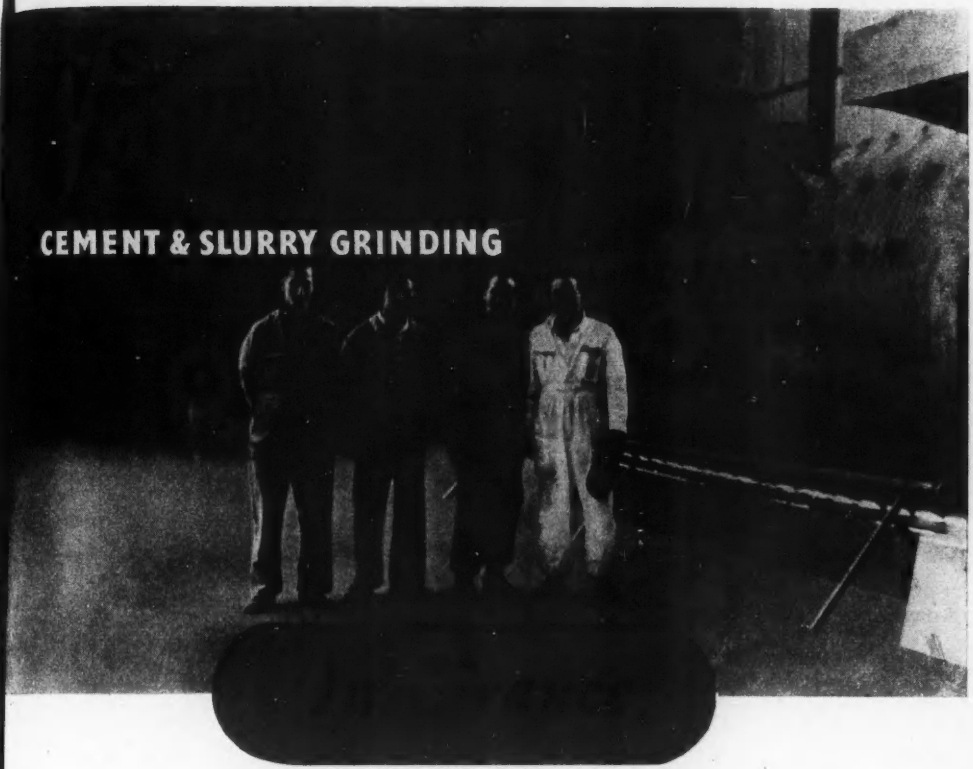

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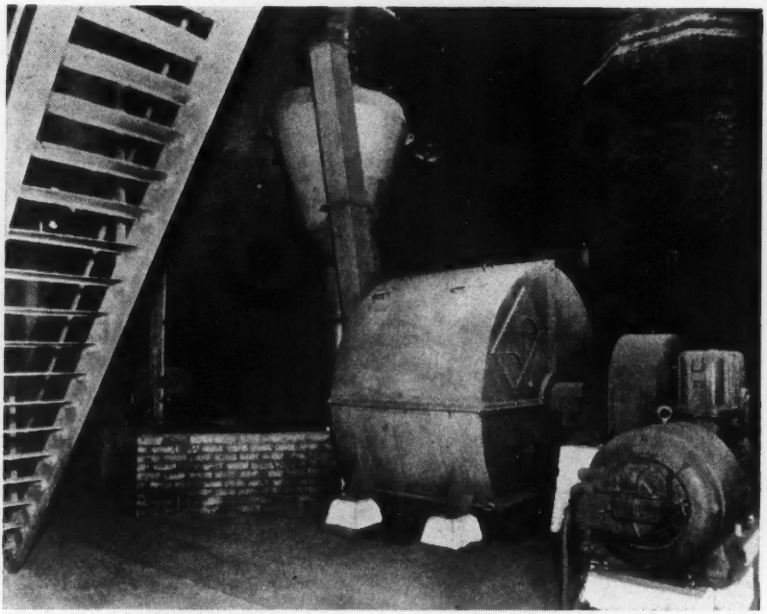

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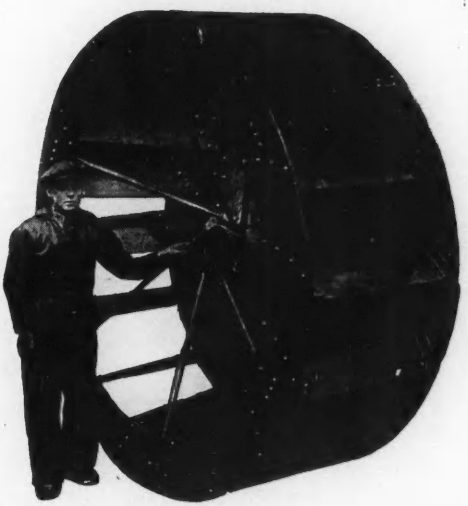

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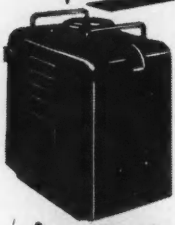

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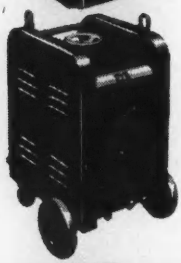

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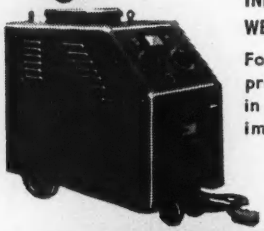

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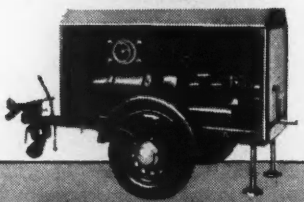

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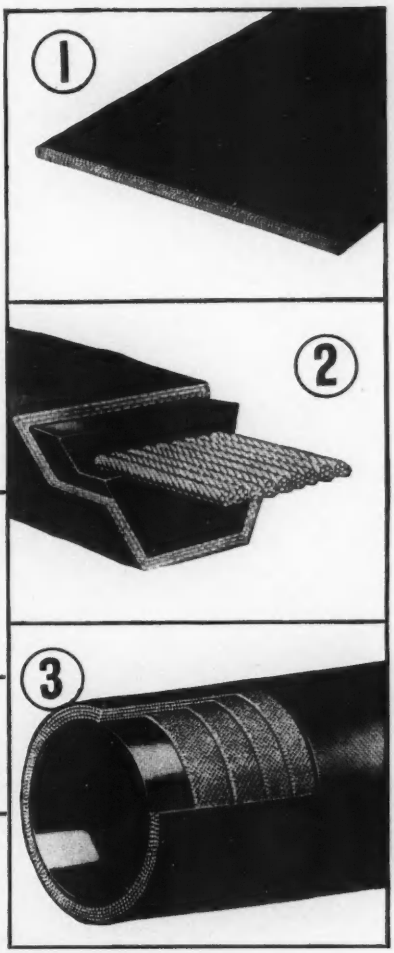

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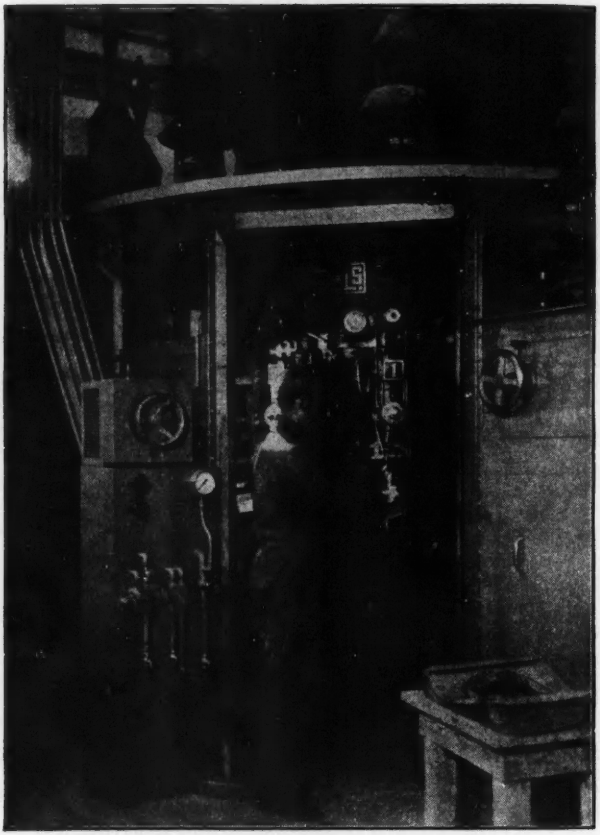

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Fifty Years of Cement Chemistry and Manufacture.

IN a paper read before the German Cement Association at Düsseldorf in April, 1951, Dr. Hans Kühl reviewed the development of the chemistry of cement in theory and practice during the past fifty years. The factors concerning cement manufacture are considered principally, the hydration processes being dealt with in less detail. The following is a summary of the paper.

For a study of Portland cement at the turn of the century the analyses of that period are not helpful, because rarely do the analyses give the alumina and iron-oxide contents separately, which shows that there was no clear realisation of the significance of the individual hydraulic factors. It was sufficient if the hydraulic modulus offered guidance for the preparation of the raw mixture. It was known that the hydraulic modulus of cement rich in silicic acid might be slightly higher than that of cement containing a high proportion of alumina, but otherwise the lime content was based on trial and error and experience. There was no clear knowledge of the structure of Portland cement clinker. Throughout the early years of this century opinions differed on whether the lime in clinker is combined or free. It is remarkable that this question should be under consideration at that period because the microscopic researches of Le Chatelier in 1887 had indicated the structure of Portland cement clinker, and ten years later Törnebohm gave to the mineral constituents of clinker the names alite, belite, celite, and felite. In spite of these discoveries the constitution of Portland cement continued to be debated for a further ten years; this was because microscopic observations did not account entirely for the constitution. It was only possible to propose theories of the chemical composition of the mineral constituents, although it is surprising that Le Chatelier referred to alite as tricalcium silicate because, according to the theories then current, tetrabasic silicic acid

could combine with, at the most, two molecules of lime. The impossibility of placing lime in a stoichiometric formula of tricalcium silicate then led to much speculation.

The fact that cement chemists and manufacturers were aware of the unsatisfactory state of the science of hydraulic binding agents is shown by a competition held in Germany. The size of the task was greatly under-estimated, since in a period of two years it was required to present an explanation of the setting process of calcareous hydraulic binding agents, synthetically, analytically, microscopically, mineralogically (setting in air, fresh-water and sea-water), namely, (a) whether silicic acid, alumina, and iron oxide combine with lime as crystalloids in fixed proportions or as colloids in fluctuating proportions; (b) whether double compounds are produced between lime and silicic acid, alumina, and iron oxide, and how these compounds take part in the setting process; (c) consideration of the swelling which occurs during hydraulic setting; (d) the influence of the burning temperature and period on various hydraulic binding agents; (e) the nature of pozzolana and its setting with lime. Such ambitious aims could not be realised and some of the problems are unsolved to-day.

The clarification of the confusion about cement chemistry at the beginning of this century came from systematic research work, principally in America, on binary, ternary, quaternary, and quinary systems. Research on the lime silicic-acid system dates from 1906. Changing from the dynamic to the static method of investigation of melt equilibria has provided the basis for successful research on binary and poly-membered systems. The dynamic method, in which the time of a heating or cooling process is ascertained by means of curves from which the chemical processes are inferred, does not give good results in silicate chemistry because of secondary phenomena. In the static process a reacting system is kept at a certain temperature until a balance is reached. The balance is then fixed by cooling suddenly and the substances thus obtained are subjected to chemical and mineralogical investigation. The process is very complex in the case of the solidification product of a polyphase system. Some idea of the complexity is obtained by considering that to establish the Rankin diagram no less than 1,000 melts were prepared and examined; in many cases the necessary apparatus had to be designed and made. Great progress in optical methods of investigation have been made. Before the year 1914 attempts were made to study the constitution of Portland cement clinker by means of polished sections, a method that has been developed more recently to such a degree that surface-ground sections are replacing thin polished sections. Reference should also be made to the electronic microscope, although it has not yet produced great progress in research on cement.

The constitution of Portland cement clinker may now be regarded as in the main clarified, but this result has been reached by devious ways. For example, although Le Chatelier considered alite as tricalcium silicate, Törnebohm thought that it was a solid solution of calcareous silicates and aluminates, a view which recurred repeatedly in different forms in the decades that followed, particularly after Jaenecke described a compound (Jaeneckeit, $8CaO.Al_2O_3.2SiO_2$) which,

owing to its high alumina content, may not represent alite but may participate in its structure. It needed modern optical methods for Jaenecke's discovery to settle a difference of opinion lasting for twenty years; the solution was brought about by the slight differences in the optical properties of the compounds in Jaeneckeit.

It has never been seriously contested that belite is principally dicalcium silicate. The fact that belite can occur in different forms has led to a problem concerned mainly with the relationship between the forms of belite and the three modifications of dicalcium silicate, and the conditions under which two of the modifications can be stabilised by the formation of solid solutions.

The constitution of celite was settled in 1928 by the discovery of tetracalcium aluminate ferrite. In the production of clinker this compound crystallises last, so that microscopically it appears as filling matter between the silicate mineral constituents called light interstitial material, despite its dark colour, because due to its high powers of reflection it appears light-coloured in reflected light. There is also a dark interstitial material consisting mainly of a solidified vitreous residue or, if the clinker has cooled slowly, of aluminates, which have not been used in building up tetracalcium aluminate ferrite. That compounds rich in alumina are really concerned here is apparent from the position of the separation field of tricalcium silicate in the Rankin diagram, which commences at 1900 deg. C. near the point of tricalcium silicate and extends as a narrow sickle in the direction of the covering of alumina, so that the residual melt must be richer in alumina the farther the crystallisation process of the principal mineral has advanced. The question of the structure of the aluminate compounds produced here, which American chemists distinguish as rectangular and prismatic interstitial material, is unsolved, although it is likely that they are two modifications of tricalcium aluminate.

As regards the secondary components, there is no doubt that large quantities of magnesia are present in Portland cement clinker as free periclase crystals, which cause magnesia to blow. Small quantities of magnesia occur distributed in the tetracalcium aluminate ferrite (up to 1 per cent. to 2 per cent.), and in the residual melt which can contain up to 4 per cent. There are four possibilities for the participation of sodium oxide as, in rapidly-cooled clinkers, it may be contained partly in the residual melt or partly in solid solution in the dicalcium silicate, while with slower cooling it can again be separated from the dicalcium silicate in the form of silicate compounds, or it may form independently the compounds $8CaO.Na_2O.3Al_2O_3$ or $3CaO.2Na_2O.5Al_2O_3$. The position of potassium oxide is less complex since in the presence of sulphuric acid potassium sulphate is formed which, if not used, yields the compound $23CaO.K_2O.12SiO_2$.

High-alumina Cement.

High-alumina cement was discovered by Bied about 1910, but the early high-alumina cements differed from present-day products. It was necessary to realise that high-alumina cement is not Portland cement modified by a high content of alumina, but an entirely different binding agent the strength of which, within limits, increases with decreasing lime content. The main component is always formed of monocalcium aluminate, which in some cases can be largely replaced

by calcium dialuminate. Silicic acid yields dicalcium silicate and Gehlinite, and iron oxide, monocalcium, or dicalcium ferrite according to the amount of lime. Since the Gehlenite does influence the setting process, the raw mixture of alumina cement should be prepared on the basis of the equilibrium ratios so that the Gehlenite content is as small as possible, that is, the mixture should be adjusted mainly for monocalcium aluminate or calcium dialuminate, the intermediate range being avoided so far as possible.

Blastfurnace Slag.

At the turn of the century blastfurnace slag was a rival of Portland cement. That rivalry should ensue for many years between these high-grade binding agents may be explained by the fact that blastfurnace slag presented chemists with a difficult problem. It was not common knowledge fifty years ago that only rapidly-cooled slags of a certain chemical composition are suitable for high-grade metallurgical cements. Passow held the opinion at first that, in air granulation, the hydraulic setting powers of slags resulted from the oxidation of the sulphide sulphur, but changed his opinion when he found in synthetic melts that a certain calcium-sulphide content of the slag might be essential, or when other investigators believed that the hydraulic setting properties of slag could be appreciably increased by treating it with salt solutions or by evaporation in an autoclave. These efforts became pointless when, due mainly to Passow, it become known that in rapid cooling the slag contained latent energy which has to be released by an external impulse such as alkaline activation by lime, or by Portland cement clinker. This fact provided a firm basis for the manufacture of iron-Portland and blastfurnace-slag cement, with which was associated, after the discovery of sulphate excitation in 1908, gypsum-slag cement.

Comparing blastfurnace slag and Portland cement as regards scientific research at the beginning of this century it is seen that slag was considerably in advance because, while at that time research into binary and multiple systems was still in its infancy, the principles of the action of slag had been clarified by the work of Passow. This was due to the fact that vitreous slag is a monophase system and Portland cement clinker a polyphase system. It follows, therefore, that research on slag was less a question of constitution than of hydration and the use of metallurgical cements.

Equipment of Cement Works.

Even the most efficient cement works was very different at the beginning of the century from what it is now. The annual capacity was as a rule 50,000 tons. In the quarry, there was generally only manual labour, and sometimes the raw material was conveyed by hand-carts to primary disintegrators, which consisted generally of stone breakers or rolling mills. Wet preparation was confined almost entirely to soft raw materials, the wet grinding of hard raw materials was still in its infancy, and the further development of wet grinding by sludge filtration came into use on a large scale only during the first world war, while the flotation process was introduced much more recently. Grinding mills were used very largely for grinding the clinker but were replaced first by the combination of ball

mill and rod mill, which developed later into the combination mill. An intermediate stage was represented by high-speed mills which acted by centrifugal force. The use of air separation was in its infancy and air-current mills in conjunction with grinding and drying only came into use in the past few decades. Throughout the whole period there was a dispute about the suitability of air separation for grinding cements and cement raw materials, a difference of opinion which is not yet settled.

Circular kilns and kilns with overlying beds had, at the beginning of the century, been largely replaced by the Schneider kiln, that is the old Hauenschild shaft-kiln, which successfully combated suspension as it protected the kiln lining from the action of the ash from the coarse coke which was then without exception the only fuel. The first rotary kiln was erected in Germany in 1896 by Forell at Lollar, and had a daily output of 30 tons to 35 tons. Large rotary kilns appeared in 1898 and 1899. The further rapid introduction of rotary kilns appeared at first to threaten the shaft kiln with extinction, for clinker from rotary kilns was superior owing to the absence of lightly-burnt materials; however, the high fuel consumption of the rotary kilns of that time was an obstacle to their increased use. An important change occurred about 1910, when the shaft kiln was rendered automatic by Hauenschild. The kiln was fired with coarse coke, until shortly before 1914 broken coke was employed more. There seemed at first to be no remedy for the very high fuel consumption of rotary kilns, which was almost twice that of shaft kilns. Attempts were made to improve heat economy by making the kilns longer, but without obtaining any outstanding effect. Other unsuccessful attempts in 1910 included altering the speed of rotation, the degree of filling, and the supply of air and coal dust. It seemed to the author that the lack of economy of rotary kilns was due to the fact that the incandescent gases passed over the mass in motion on the bed of the kiln without coming into close contact therewith, and led to his method of atomising the slurry or distributing the slurry mechanically. As is well known, these suggestions were put into effect many years later in the Rigby process, in the introduction of chains, and in preheating apparatus such as the calcinator and slurry dryer. Later, the intensive heat exchange between the raw material and the incandescent gas vapour in the Lepol kiln was put into effect by the Lellep grate and again later by the sinter-band, on which the calcining process takes place quite differently.

Dust elimination at the beginning of the century was carried out solely by filters. Individual electric drives were not used, all machines being operated from complex transmission equipment. Cement was packed mainly in drums and partly in jute bags tied with strips of sacking. It was considered to be a great advance at the time when the strips were replaced by mechanically-placed wires. Soon after the first world war paper bags and valve bag-packing machines appeared.

Quality and Tests of Cement.

Compared with present-day standards, the strengths of cement fifty years ago were modest, and were liable to considerable fluctuations. Some older works were supplying cement that often failed to satisfy the standard requirement of

a tensile strength of about 230 lb. per square inch at 28 days, although many works made excellent cement. Among the cements tested by the author in 1908, the tensile strengths at three days varied from 90 lb. to 300 lb. per square inch and at 28 days from 170 lb. to 385 lb. per square inch. The fluctuation of the compressive strength was greater and at 28 days was from 1,140 lb. to 5,400 lb. per square inch. Classification of cements according to their strength came about shortly before the first world war.

Fifty years ago the International Association for Testing Technical Materials attempted to make uniform the highly divergent standards of the various countries, but so far all attempts in this direction have failed. Indeed, the rules for tests are diverging more and more. The methods of test have not only changed in fifty years but the strength demanded has been raised from time to time. In the early decades cement was tested for tensile strength only. A few years before the first world war the tensile-strength test was replaced in Germany by the compressive-strength test, and at the same time combined storage of test pieces was introduced. Although on the introduction of this method there was no lack of warning, this method of testing, which has resulted in successive increases of compressive strength at the expense of tensile strength, remained in force until the comprehensive work of Haegermann resulted in the knowledge that the plastic test on mortars with mixed-grained sand gives a far more reliable assessment than the old test with earth-moist mortars and coarse standard sand.

Hydration.

At the beginning of this century the dispute between the theories of crystalline setting (after Le Chatelier) and colloidal setting (after Michaelis) was unsettled. Even in 1905-7 Michaelis was strongly contradicted when he developed his theory in detail. Posterity has realised that the difference of opinion between Le Chatelier and Michaelis was by no means as great as it appeared, and if to-day hydraulic setting is regarded as a colloid-chemical process in the sense of Michaelis's theory, it is not denied that the compounds are micro-crystalline forms, which constitute the dispersed phase of the colloidal system.

If on the whole unity prevails, research into the new compounds produced by the setting process is far from reaching the same level as the research on the constitution of Portland cement clinker. Not long ago it was thought possible to read the composition of the new compounds from the binary systems lime-silicic acid, lime-clay, and lime iron-oxide. The discovery of a Gehlenite hydrate showed that possibly quaternary compounds, perhaps resembling zeolith, must be considered. Still more complicated is the problem set by recent American research in which it has been shown that in garnets silicic acid can be replaced by water, and the aluminates thus produced can form solid solutions with one another and with the original substance; perhaps it will be deemed necessary to take this formation into consideration.

A Pulverised-Fuel Plant.

THE pulverised-fuel plant described in the following has been installed at the works at West Thurrock, Essex, of the Lafarge Aluminous Cement Co., Ltd., to produce, at the rate of 3½ tons per hour, pulverised fuel to a fineness of 95 per cent. passing a No. 170 B.S. sieve. The plant is also capable of an output of 4·7 tons per hour of pulverised fuel of which 92 to 93 per cent. passes a No. 170 B.S. sieve. The plant was supplied by the British " Rema " Manufacturing Co., Ltd., of Sheffield.

Since the kilns are at some distance from each other and from the building

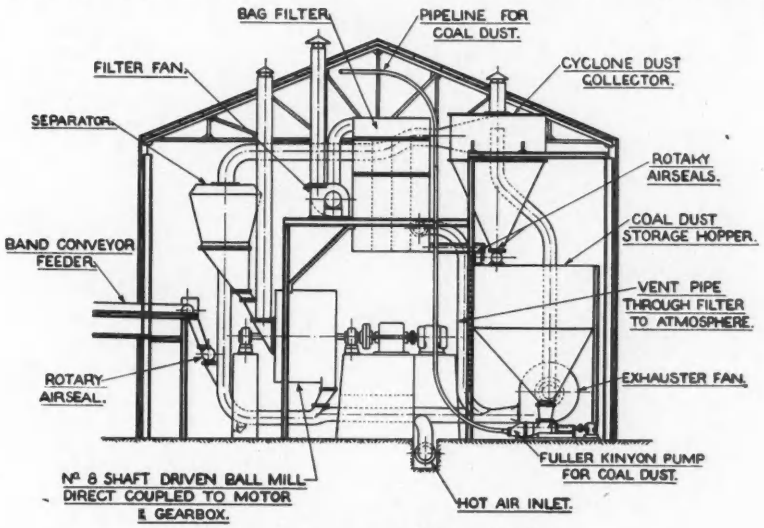


Fig 1.—Arrangement of Storage Plant.

which houses the coal plant, the pulverised fuel is pumped to storage hoppers adjacent to the kilns. The arrangement of the plant is shown in *Fig.* 1. *Fig.* 2 shows the central-shaft-driven ball mill complete with a vacuum system of air separation. To the left is the belt-conveyor carrying raw coal from storage, followed by the rotary discharge valve through which raw coal is introduced to the vertical drying pipe. The mill is completely above ground level, and is supported on roller bearings. The drive is through a totally-enclosed double-helical reduction gear, whose output shaft is connected to the main shaft of the mill. There are no intermediate gears or countershaft, so that the installation provides a totally-enclosed oil-immersed drive of high efficiency and completely dustproof.

Fig. 3 shows the feed-inlet end of the mill. Coal which has been dried, ground and classified, is carried pneumatically to a cyclone collector, and the cleaned air passes to a British " Rema " heavy steel-plate type exhauster fan (*Fig.* 4). The shaft assembly for this fan incorporates double-row self-aligning roller bearings fitted in water-jacketed housings. Some of the air handled by the fan is recirculated through the pulverising system, although a proportion of the air is diverted to a

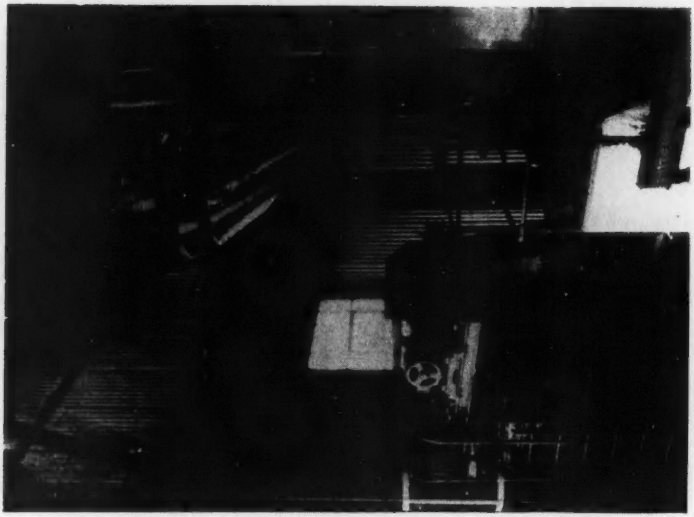


Fig. 3.—Feed End of Mill.

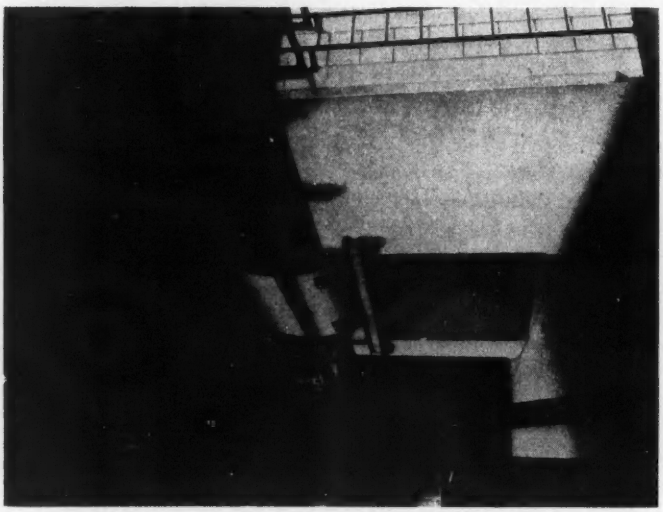


Fig. 2.—The Mill.

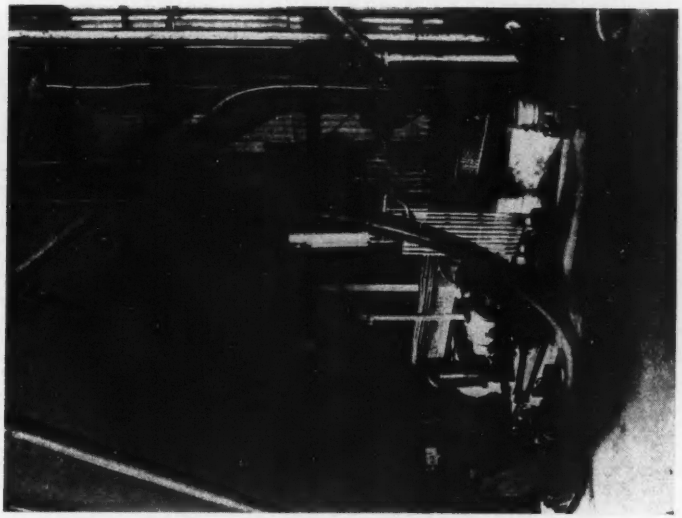


Fig. 5.—Fuel Hopper, Pump and Compressor.

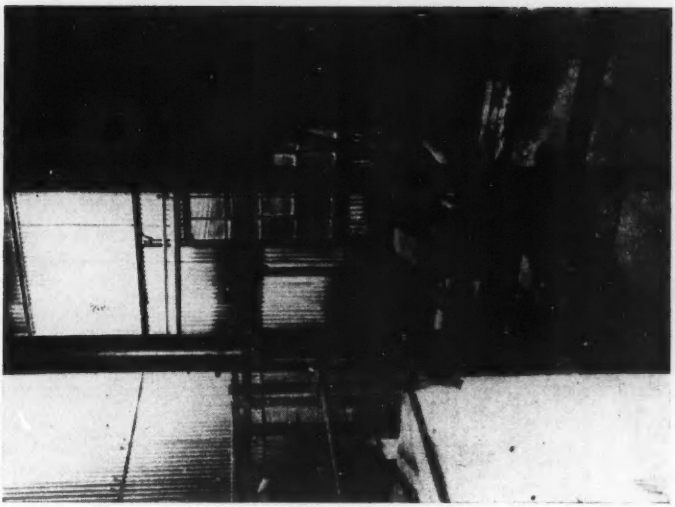


Fig. 4.—The Exhauster Fan.

totally-enclosed automatic Visco filter which removes the dust before the air is passed to the atmosphere. From the cyclone collector, pulverised fuel is discharged through a motor-driven rotary valve into a hopper.

From this point the fuel is dealt with by a Fuller-Kinyon pump. *Fig.* 5 shows the pulverised-fuel hopper, the pump, and the rotary air-compressor. This system permits fuel from the storage hopper to be delivered to any one of a number of storage hoppers situated in the adjacent kiln house. The conveying system employs a pipeline of relatively small bore, to which is fitted a number of two-way valves to permit diversion of the fuel to any one of the hoppers.

The control gear includes an illuminated diagram which indicates the flow from the pump of aerated pulverised fuel and the hopper to which it is being delivered. Electrically-operated valves determine which hopper shall be served. The various hoppers are sited to supply the kilns, and the bin-and-feeder system of firing is employed. Duplex-type screw-feeders provided with variable-speed mechanism are installed on each hopper. In spite of the fine nature of the finished pulverised fuel, the plant is economical in power requirements. The mill is driven by a 90 h.p. 720 r.p.m. motor and the main exhauster fan by a 50 h.p. motor at 1,440 r.p.m.

False Set of Portland Cement.

IN a recent discussion on the so-called " false set " of Portland cement Messrs. R. F. Blanks and J. L. Gilliland (of the U.S.A. Bureau of Reclamation) stated that reducing grinding temperatures by using cool clinker and water-sprays on the mills has been very successful in preventing false set, and wherever proper precautions to cool the mills had been taken, false set had disappeared.

It was generally agreed that premature stiffening was usually caused by unstable gypsum, and the most common cause of unstable gypsum in cement was a high grinding temperature. Instability was also affected by storage temperatures, aeration, and moisture. Another possible approach was to use stable calcium sulphate, either natural anhydrite or gypsum which had been calcined to form insoluble anhydrite. Limited tests had shown that low-alumina cements may be adequately regulated with these materials. In some cases the addition of an admixture at the mixer had relieved false set in cement.

Mr. Myron A. Swayze said that dehydrated gypsum was one of the reasons for false set, but not the only reason. Grinding temperatures could be controlled, but many factors contributing to false set were beyond control of the cement maker.

A New Vertical Lime Kiln.

A NEW type of vertical down-draught lime kiln was described at the last annual meeting of the U.S. National Lime Association by Mr. F. G. Schwalbe, of the Toledo Engineering Co., Inc. This kiln, known as the Arnold and Weigel kiln, was described as an "upside down" kiln. It has not yet gone beyond the laboratory stage.

In a glass-making furnace the radiation and convection losses in the burning zone form 50 to 60 per cent. of the total fuel requirements, whereas in a vertical lime kiln they form only 2 to 3 per cent. An increase in the production of a lime kiln can therefore effect only a small percentage of reduction in the fuel required per unit of output. Any new kiln can as a result offer only limited heat-saving possibilities. It should, instead, permit the fuel to be burned in an efficient manner and uniform burning and flexibility. This combination can be obtained only by following the principles applying to glass-melting furnaces, open-hearth

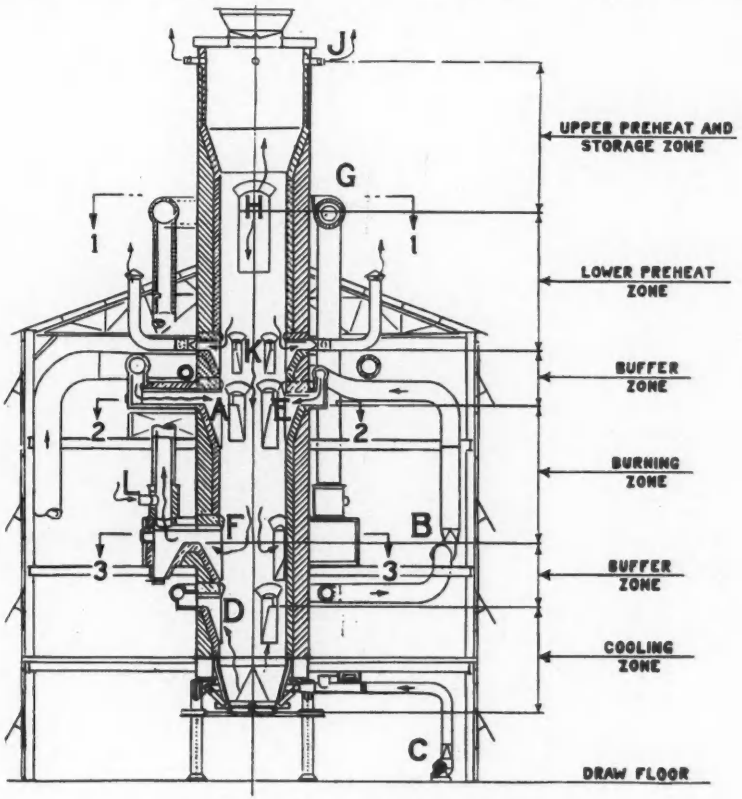


Fig. 1.—A Down-draught Vertical Kiln.

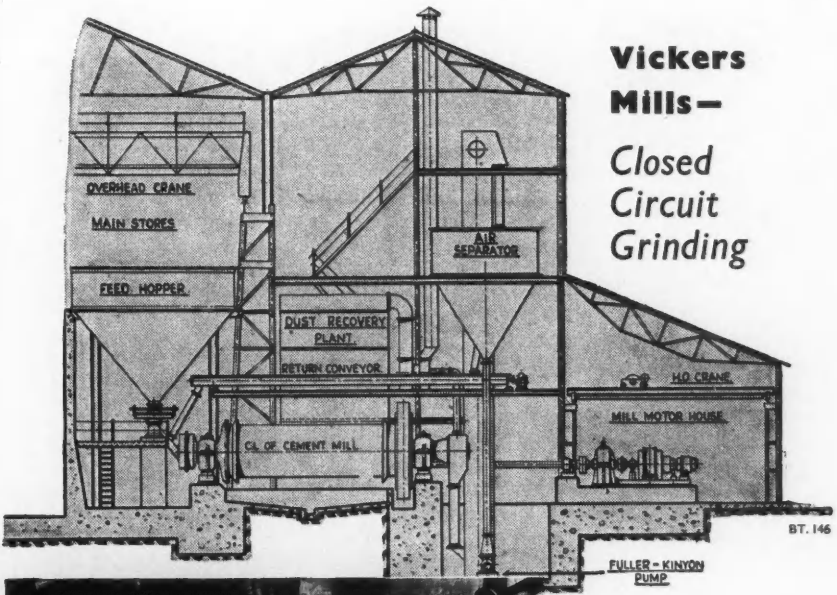
furnaces, and other types of processing furnaces. It is necessary that (1) gases being heated shall travel upward through the heating medium, and (2) gases giving up heat or cooling shall travel downward through the cooling medium. The conventional type of vertical lime kiln utilizes these principles only in one respect, namely, the cooling air entering the base of the kiln is heated as it passes upward through the burned lime. The Arnold & Weigel kiln incorporates both principles.

Fig. 1 is a vertical cross section of the kiln. Fan C delivers to the bottom of the cooling zone air 40 per cent. in excess of that required for combustion, and the preheated combustion air, plus 8 per cent. excess, is drawn from the top of the cooler through ports D. The remainder of the air flows upward to the burning zone exhaust ports F. This forms a gaseous seal which prevents the CO_2 in the burning-zone gases from passing through the cooling lime and subjecting it to recarbonization. It is calculated that this upward-flowing air will uniformly cool the lime to 250 deg. F.

The gas fuel is introduced to the kiln through ports A. The pre-heated combustion air from the cooling zone is introduced by fan B back into the kiln through port E. At this point near-atmospheric pressure is maintained and, as the gas and air mix in the burning zone, combustion takes place and the products of combustion are made to flow downward. With the CO_2 from the stone and the excess air from the cooler they are withdrawn through ports F by fans C. As the temperature of these mixed gases is too high for handling by a fan, blending air is introduced to maintain a temperature of about 1400 deg. F. The burning-zone fans G then return the mixture to the kiln through ports H. About 23 per cent. of these gases move upward and maintain a positive pressure in the upper preheating zone. Adjustable vents J are provided to permit the cooled gases and moisture from the stone to discharge from the kiln at about 300 deg. F. The rest of these gases flow downward to effect uniform preheating of the stone, and these leave the lower preheating zone through vents K at about 1200 deg. F. Between the vents K and the fuel and combustion air ports A and E is a buffer-zone of preheated stone. The pressure created forms a gaseous seal which prevents fuel gas and combustion air from travelling upward. This kiln can burn different sizes of stone and operate at different capacities without affecting its heat balance. The theoretical lime-coal ratio is 4·32 to 1 and the heat required per lb. of lime is 2748 B.T.U. The foregoing notes are from *Pit and Quarry* for November 1951.

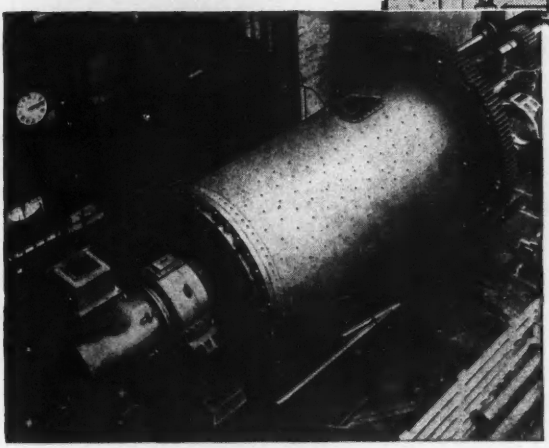
A New Kiln for Rhodesia.

THE Rhodesian Cement Co., Ltd., is reported to have entered into a contract for the erection of a third kiln which is expected to be in production in the summer of 1953, and will increase the capacity of the Colleen Bawn factory to about 250,000 tons a year.



Vickers Mills—

Closed Circuit Grinding



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Measuring the Degree of Burning of Clinker.

A METHOD of assessing the degree of burning of Portland cement clinker by measuring its porosity has been devised by Mr. T. Yoshii and Mr. Y. Mura Kami, of the Chichibu Cement Co., of Japan. The apparatus used is a porosimeter used for ascertaining the porosity of concretes and mortars, and is shown in *Fig.* 1. The procedure is as follows: (1) A sample of cooled clinker is placed in the bulb (A) so that it is almost full; (2) after opening cocks 1 and 2, the mercury in the burette (B) is raised until the air contained in bulb A between cocks 1 and 2 is completely expelled; (3) the burette is then moved downward until a vacuum is obtained in the bulb. The air in the clinker pores then diffuses into the vacuum and the amount of air contained in the pores can be determined by reading the mercury column. This method is claimed to be more accurate than that in which the degree of burning is assessed by the weight of a 1-litre sample of the clinker. The relation between porosity and the weight per litre in grammes is shown in *Fig.* 2.

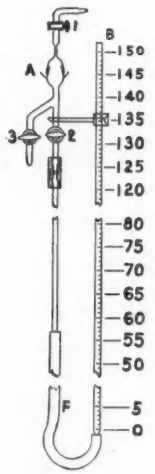

Fig. 1.

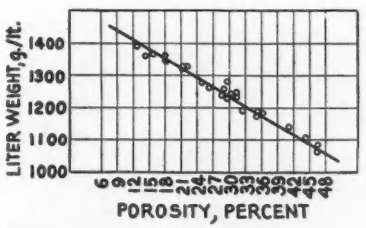

Fig. 2.—Relation between Porosity and Weight per Litre of Clinker.

In the course of a report published in "Rock Products" for November, 1951, the authors state that a rise of 0·1 per cent. in the hydraulic modulus of clinker corresponds to a rise of 4 to 5 per cent. in porosity. In underburned clinker, free CaO increases rapidly with porosity. For a given porosity, free CaO fluctuated within a limit of 1·7 per cent. Free CaO content rose with an increase in the hydraulic modulus, but free CaO and porosity had a logarithmic relation. The amount of free CaO in the clinker was affected by both the hydraulic modulus and the degree of burning. If the free CaO in the clinker exceeded 1·5 per cent., the cement became unsound. In tests on the relation between the strength of

cement and the porosity of the clinker it was found that the cement with the highest compressive strength was obtained with clinker having a porosity of about 34 per cent. It is concluded from this that excessive burning of clinker should be avoided, and that burning should be within the limit of allowable free CaO content. Most clinker in Japan was overburned, with consequent waste of fuel and reduction in the hydraulic properties of the cement. This tendency was more noticeable in the case of low-lime clinker produced in relatively short kilns by the dry process. Clinkers with a high lime content should be burnt harder than clinkers with a low lime content, perhaps to a porosity of only 25 per cent.

Cement for Underwater Construction.

INFORMATION on recent tests in Germany on the effect on concrete of sea-water and of sodium sulphate in underwater construction is given in two publications issued by Wilhelm Ernst & Sohn, of Berlin.

In "Beton und Zement im Seewasser," by A. Eckhardt and P. W. Kronsbein (Price 6.50 DM.) a report is given of tests made at Wilhelmshaven Marine Research Station on specimens of 1:3, 1:4 and 1:5 concrete using different types of cement. The 1:3 concrete only was satisfactory, and cubes stored in seawater for thirteen years showed that only those made with high-alumina cement were completely satisfactory. The conclusions are briefly that concrete in seawater must be dense and have at least 680 lb. of cement per cubic yard. The water content should not exceed the amount required for maximum density, and the concrete should be placed in the dry, or, where placing under water is unavoidable, a tremie should be used. Construction using large concrete blocks is very satisfactory. Rounded gravel aggregate is preferable. The compressive strength of the cement is not so important as its rapid-hardening properties and resistance to chemical attack. Cements deficient in lime are recommended, and the addition of trass, without reducing the quantity of cement, is advisable.

"Bindemittel für Massenbeton," by K. Walz (Price 5.50 DM.), is a report of a German committee. Favourable results of the use of binding agents composed of a mixture of cement, lime, and trass for mass concrete in underwater work 30 to 40 years ago led to tests from 1941 onwards on prisms 4 cm. square and 16 cm. high placed for 5½ years alternately in air and half submerged in a sodium-sulphate solution. Specimens mixed in the proportions of 35 per cent. of Portland cement, 10 per cent. of lime, and 55 per cent. of trass showed the greatest resistance to chemical attack. Specimens made of cement and trass showed some signs of deterioration, and those of cement only disintegrated completely.

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Research on Cement.

THE following notes on research on cements is taken from the report of the Building Research Board for the year 1950 (issued in December, 1951, by H.M. Stationery Office. Price 4s.).

Reports have been prepared for publication on the structure of tricalcium silicate ($3CaO.SiO_2$) and on the system $CaO\text{-}SiO_2\text{-}H_2O$ at 18 deg. C. A review of hydrothermal reactions has been published, and some work on these reactions, which are important in connection with steam-curing of concrete products, is proceeding. The same form of hydrated calcium silicate is formed over a wide range of temperatures; that formed at the higher temperatures is better crystallised and promises to be more suitable for a determination of its structure. The dehydration isobars of this compound are being determined.

It has been possible to refine the structure previously postulated for dicalcium silicate ($2CaO.SiO_2$), and it is hoped to be able to define the relation between this compound and certain others, such as merwinite ($3CaO.MgO.2SiO_2$), which are associated with it in slags and cements. Automatic equipment for reproducing continuous cycles of heating and cooling has provided important information on this subject, and an increase in the safe working limit of the laboratory furnaces from 1650 deg. C. to 1750 deg. C. should help in gathering new data. A theoretical study of the differential thermal analysis method is in progress.

An important step in the study of high-alumina cement was realised during the year by the identification of the mineral usually known as "unstable $5CaO.3Al_2O_3$" as a quaternary compound $6CaO.4Al_2O_3.(MgFe)O.SiO_2$.

A large number of blastfurnace slags has been collected. The mineralogical findings on these slags have recently been reviewed and the results compared with those predicted from a knowledge of the system $CaO\text{-}MgO\text{-}Al_2O_3SiO_2$-. This study formed the subject of a paper at a recent conference on the utilisation of slags organised by the Association Belge pour favouriser l'Etude des Verres et Composés Silicieux. The successful separation of minerals from blastfurnace slags has revived the hope that it may be possible to extract the main constituents of Portland cement for analysis and mineralogical study. Some preliminary work is in progress.

A comparison has been made, in co-operation with the U.S.A. Portland Cement Association between the British and U.S.A. Standard methods for determining cement fineness.

In connection with an investigation for Uganda Cement Industries, a formula was found for proportioning phosphate-bearing raw materials which avoids risk of unsoundness in the cement. If the cement is to satisfy the strength requirements of B.S. No. 12 for ordinary Portland cement, the P_2O_5 content must not exceed 2 to $2\frac{1}{4}$ per cent. The effect of these requirements is to limit the possible range of proportions of raw materials, but the range is sufficient for normal working even with a dry process. After the nodulising properties of the raw materials had been studied in the laboratory, several hundredweights of cement clinker were produced in a small rotary kiln for study of the properties of concrete made with cement prepared from it.

The Cement Industry Abroad.

Cement Production in the U.S.A.

A REPORT of the Bureau of Labour's Branch of the U.S.A. Division of Productivity and Technological Developments shows that the number of man-hours needed to produce cement was reduced by 8 per cent. between the years 1949 and 1950. This is the lowest on record and is largely attributed to a continuation of the trend in despatching cement loose instead of in bags and to the fuller employment of the capacity of the industry. Taking the index of man-hours per unit of output as 100 in the year 1939, it declined to 119.4 in 1944 and has since improved year by year to 76.5 in the year 1950. The proportion utilised of the total capacity of the industry was 48 per cent. in 1939, 38 per cent. in 1944 and 81 per cent. in the years 1949 and 1950.

Cement Factory for Iraq.

IT is stated that the Development Board of the Iraqi Government is to build a cement factory near Kirkup to supply cement for the Board's undertakings and for other purposes. It is stated that there is an acute scarcity of cement in Iraq, and that the price has recently increased by one-third. The importation of 85,000 tons of cement has been authorised, of which 25,000 tons is for the use of the Development Board and the rest for other purposes.

Cement Production in Dominica.

IT is reported that the cement works at Ciudad Trujillo has now reached its maximum capacity of 12,000 bags a day. This is sufficient for the present consumption in the Dominican Republic, and imports will no longer be necessary.

New Cement Works in Mocambique.

A NEW cement factory is to be built at Matola, Mocambique, Portuguese East Africa, by Companhia de Cemento de Mocambique, Lda. (P.O. Box 270, Lourenco Marques). This will be the third cement works in Mocambique.

New Cement Works in Argentine.

IT is stated that a new works is to be built in the province of San Luis with an annual capacity of 200,000 tons of cement and 90,000 tons of lime, and which will also distil alcohol from wood.

Cement Works in Paraguay.

IT is reported that the new cement works at Valle-Mi, Paraguay, is now complete. One kiln is now in operation, and is expected to produce 2000 tons a day.

Pneumatic Conveyors.

A PUBLICATION of 80 pages, entitled " Pneumatic Conveying Installations," has been issued by Messrs. Davidson & Co., Ltd., Sirocco Engineering Works, Belfast. This Company's system is fully described and illustrated, and much useful information is given on the handling of materials that can be economically conveyed pneumatically.

ALUMANTINE

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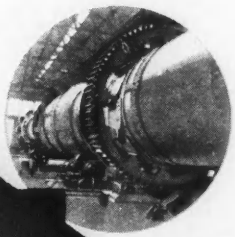

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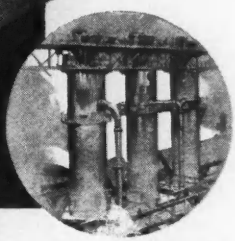

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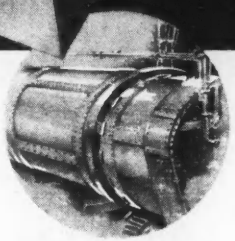

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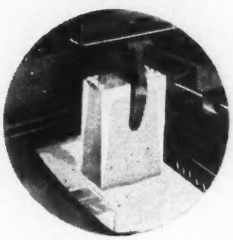

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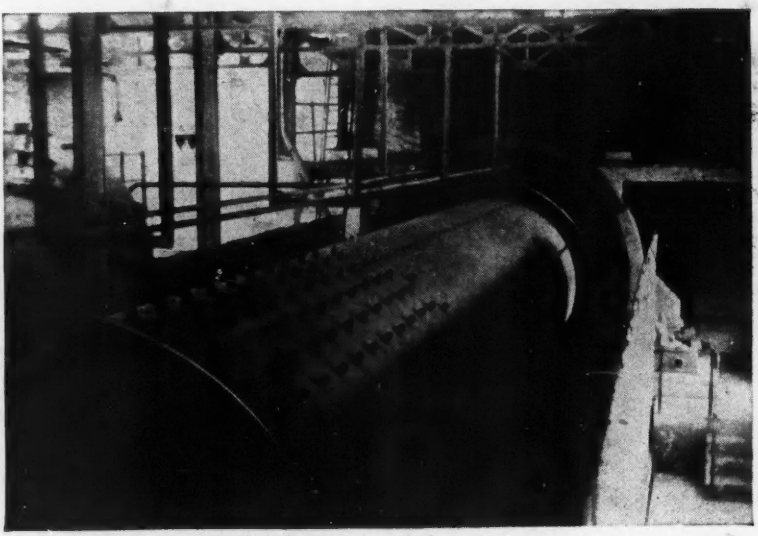

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